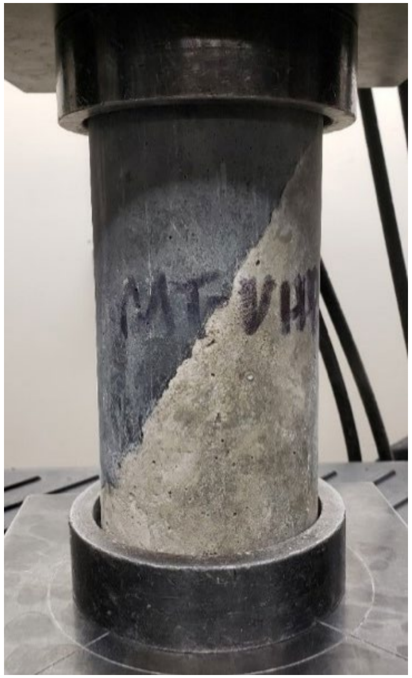
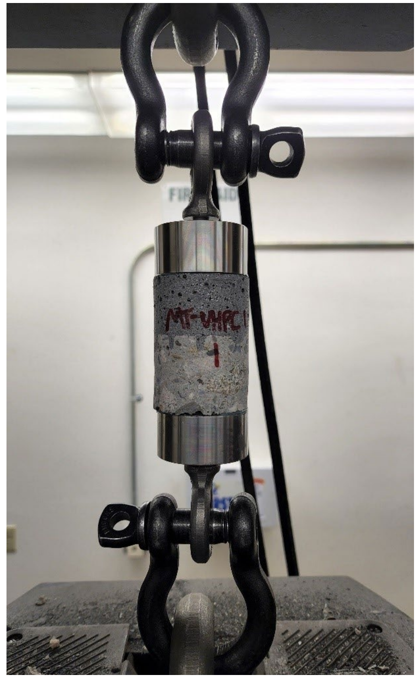
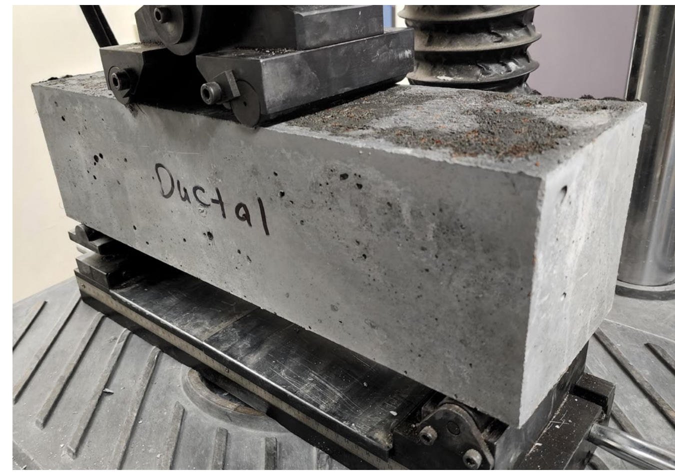
Exploration of UHPC Applications for Montana Bridges – Intermediate TP Meeting







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UHPC Project Background

- Phase 1 – Feasibility
  - We can make UHPC with materials readily available in Montana
- Phase 2 – Field Application and Sensitivity Study
  - Changes in constituent materials and batch size
  - Bonding properties and pull-out strengths
- Phase 3 – Implementation
  - Concurrent research on the first use of MT-UHPC for field cast joints
  - Investigate constructability issues that may hinder use of MT-UHPC in future applications

Applications Project Scope

Task 1 – Literature Review

Task 2 – Material-Level Evaluation

Intermediate Technical Panel Meeting

Task 3 – Experimental Design of Structural Testing

Task 4 – Structural Testing

Task 5 – Analysis of Results and Reporting

Task 1 - Literature Review

- UHPC has potential for use as a bridge deck overlay material
  - Several studies – Iowa State, New Mexico State, and Missouri S&T
  - Thixotropic mix design needed for cross slope and superelevation
  - Most other state DOT's using proprietary mixes and special equipment to mix and place overlays
  - Underlying concrete surface preparation required for adequate bond with UHPC overlays
- Steel girder repair has been proven with large scale testing
  - University of Connecticut
  - All UHPC repair methods were shown to increase capacity compared to undamaged girders.
  - FEA model developed

Task 2 – Material-Level Evaluation

- Investigated 3 UHPC mixes
  - MT-UHPC
  - MT-UHPC with viscosity modifying admixture for thixotropy (MT-UHPC-T)
  - Proprietary thixotropic Ductal mix (Ductal-T)
- Experimental Testing
  - Compression Testing
  - Flexural Testing
  - Direct Tension Testing
  - Slant Shear Testing

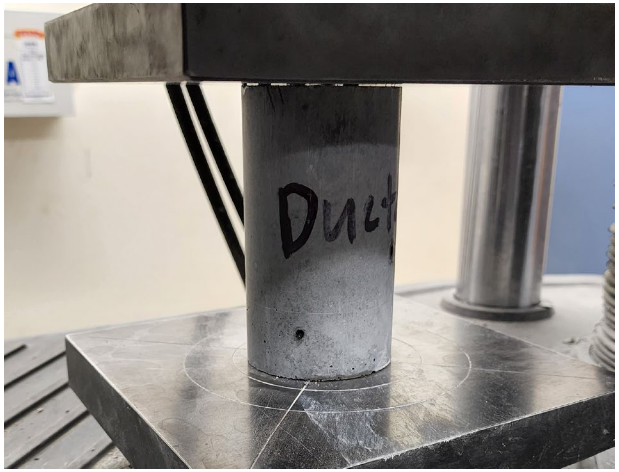
Discussion on Thixotropy

UHPC Mixes

- MT-UHPC and MT-UHPC-T
  - Developed from past research at MSU
  - Only difference with MT-UHPC-T is the addition of MasterMatrix UW 450 viscosity modifying admixture
- Ductal-T
  - Proprietary
  - Premix supplied
  - Higher dynamic flows
- Cor-Tuf

Testing – Material Strengths

- Compression – ASTM C1856 and C39
  - 7,14, and 28 day strengths on UHPC
  - Bond test day strengths on substrate concrete
- Flexure/Ultimate Tensile – ASTM C1609
  - Performed on UHPC at 28 days

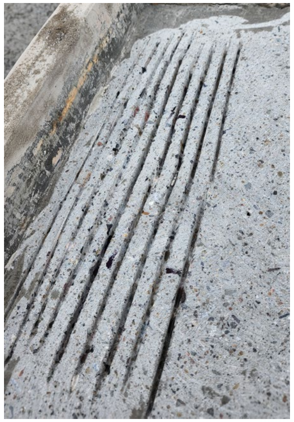


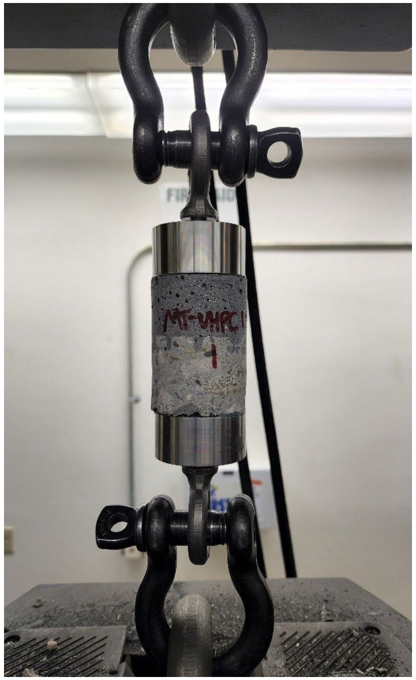
Results – Material Strengths

	Flow (in)		Compressive Strength, f'c (ksi)			Ultimate Tensile Strength (ksi)		
UHPC Type	Static	Dynamic	7-Day	14-Day	28-Day	Measured	Predicted	Meas/Pred
MT-UHPC	10.25	-	14.3	15.1	17	3.37	0.978	3.45
MT-UHPC-T	4	5.5	11.6	-	15.4	2.8	0.931	3.01
Ductal	4	6.5	15.1	17.3	17.4	3.43	0.989	3.47

Testing – Direct Tension

- Direct Tension – ASTM C1583
  - Create slab of substrate concrete
  - Prepare surfaces – typical, cross-hatch, and chipped
  - Apply overlay material
  - Core and prep samples
  - Test in MTS tension



Results – Direct Tension

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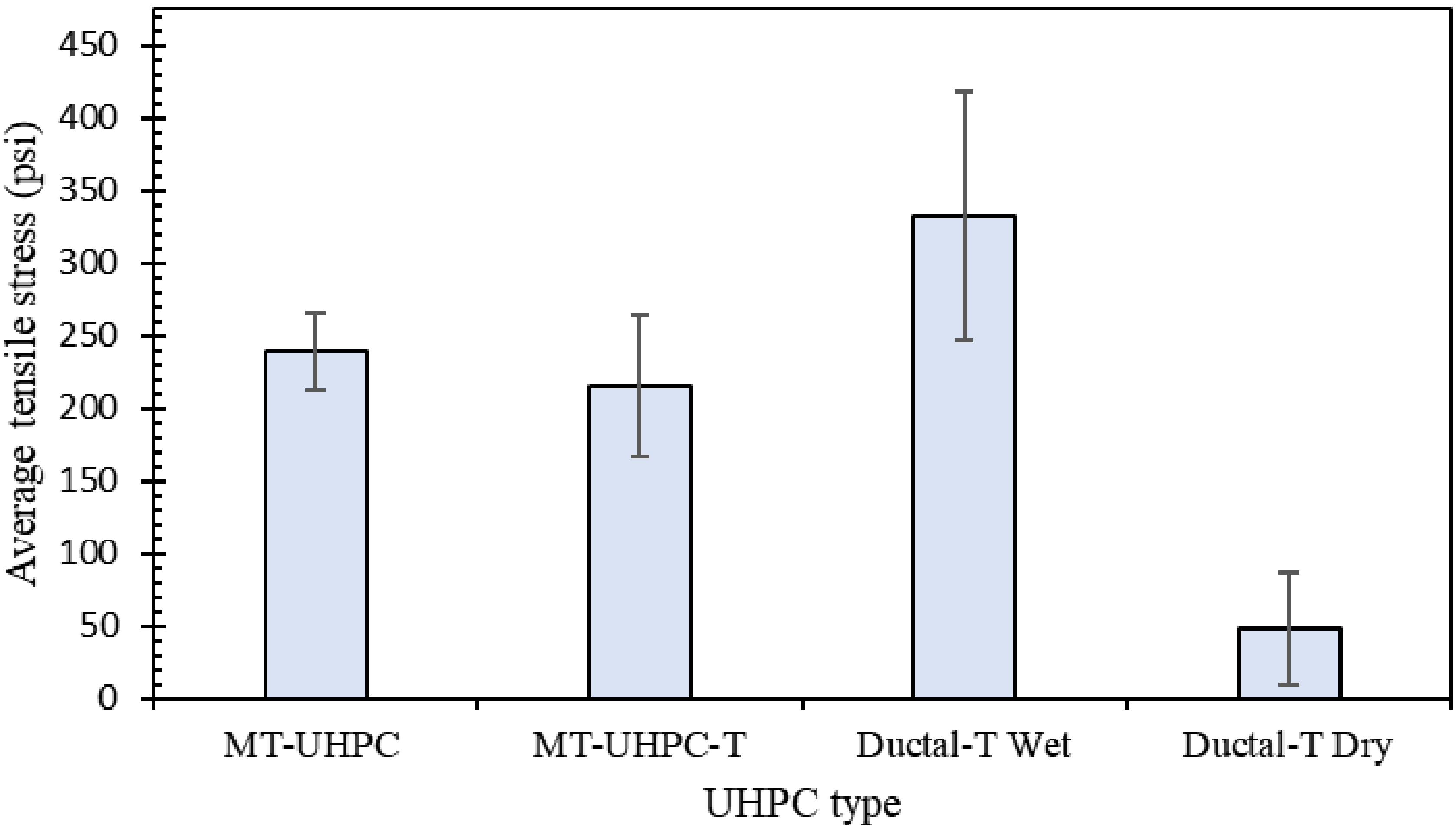
Groove Pattern	Sample Number	MT-UHPC (psi)	MT-UHPC-T (psi)	Ductal-T (psi)	
				Wet	Dry
Typical	T1	280**	239*	197*	60*
	T2	210**	146*	332*	11*
	T3	256**	291*	433*	15*
	T4	251*	192*	367**	106*
	T5	206**	208*	-	-
	T6	234*	-	-	-
	Average	239	215	333	48
	CoV	10.90%	22.60%	25.90%	81.20%
Crosshatch	XH1	220*	148*	343*	-
	XH2	234*	161*	297*	-
	Average	227	155	320	
	CoV	3.20%	4.20%	7.10%	-
Chipped	C1	252**	-	234**	-

*Bond Failure

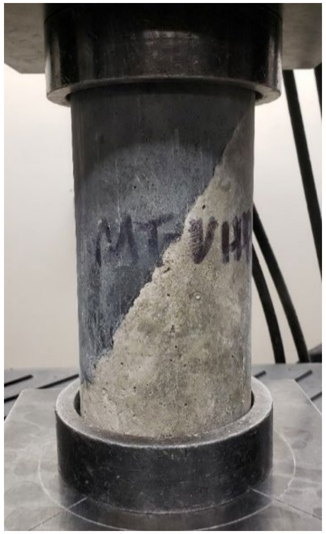
**Substrate Concrete Failure

Results – Direct Tension



Testing – Slant Shear

- Slant Shear – ASTM C882
  - Create 30-degree angle cylinders
  - Prep surfaces (same typical as direct tension)
  - Fill remaining cylinder
  - Test in MTS compression



Results – Slant Shear

Results – Slant Shear

Sample Number	Minimum Bond Shear Strength (ksi)		
	MT-UHPC	MT-UHPC-T	Ductal-T
1	2.94	3.15	3.13*
2	2.77	3.33	3.26
3	2.75	3.31	3.3
4	2.82	3.37	3.16
Average	2.82	3.29	3.24
CoV	3.02%	2.94%	2.23%

*Bond Failure

Task 2 Summary and Conclusions

- Adequate compressive and tensile strengths
- Both thixotropic mixes demonstrated the desired behavior, but the MT-UHPC-T mix requires further refinement to optimize the UW-450 admixture dosage
- All direct tension surface preparations met the ACI minimum recommendation for concrete repair
  - Surface must be wetted
- All slant shear specimens surpassed the minimum ACI recommendation though only failed at the bond

Project Schedule

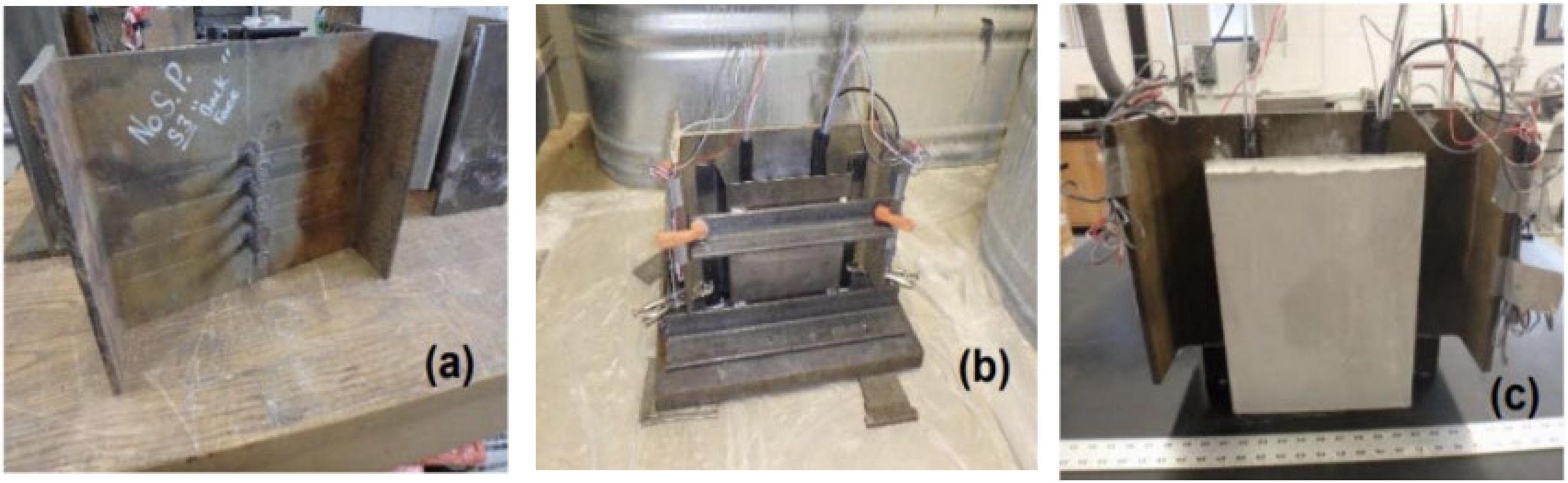
Activities	Dates	Project Quarter 1 Aug 1 - Oct 31, 2021	2 Nov 1 - Jan 31, 2022	3 Feb 1 - Apr 30, 2022	4 May 1 - Jul 31, 2022	5 Aug 1 - Oct 31, 2022	6 Nov 1 - Jan 31, 2023	7 Feb 1 - Apr 30, 2023	8 May 1 - Jul 31, 2023
Kick-off Meeting	8/2/2021	X							
Task 0 - Project Management		X	X	X	X	X	X	X	X
Task 1 - Literature Review		X	X	X	X	X	X	X	X
Task 1 Report	1/31/2022		X						
Task 2 - Material Evaluation		X	X	X					
Task 2 Report	4/29/2022			X					
Intermediate Technical Panel Meeting	5/16/2022				X				
Task 3 - Application(s) Experimental Design					X	X	X		
Task 3 Report	1/6/2023						X		
Task 4 - Testing					X	X	X	X	
Task 4 Report	2/28/2023							X	
Task 5 - Analysis of Results and Reporting								X	X
Draft Final Report	3/31/2023							X	
Project Summary Report	5/15/2023								X
Performance Measures Report	5/15/2023								X
Project Poster	5/15/2023								X
Final Report	7/3/2023								X
Final Presentation and Webinar	7/17/2023								X
Implementation Meeting	7/17/2023								X
Implementation Report	7/31/2023								X

Potential Paths for Tasks 3 and 4

- Bridge Repair
  - Steel Girder End Repairs
- Bridge Deck Overlay
  - MT-UHPC
  - Proprietary

Steel Girder End Repairs Option

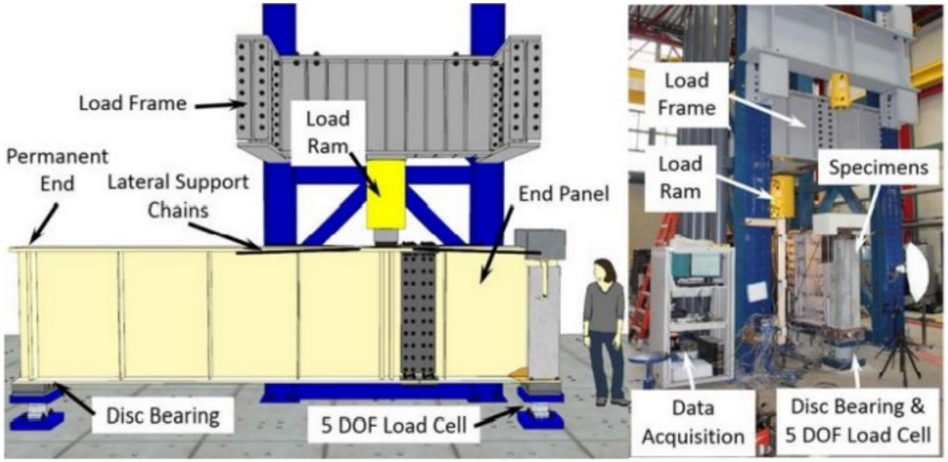
- Start with smaller-scale push-off tests to verify materials work

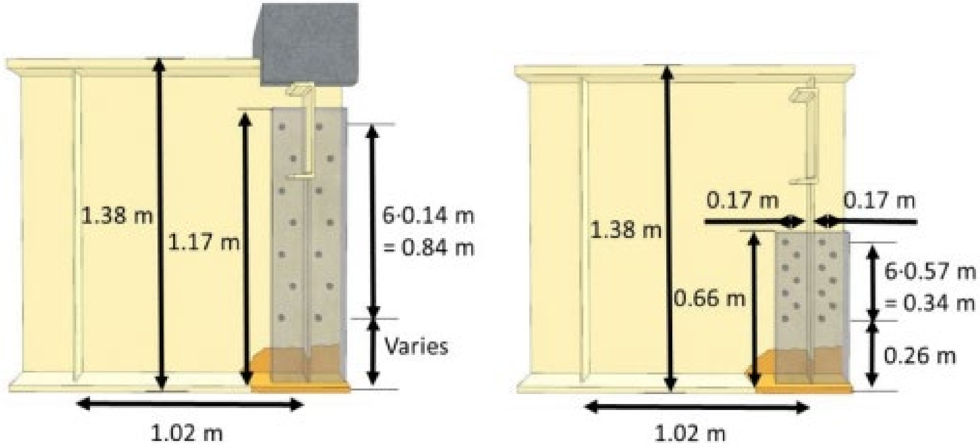


(a) Beam prior to casting; (b) beam with formwork used for casing concrete, and (c) completed push-off

Steel Girder End Repairs Option

- Work towards large-scale girders with recommended stud patterns from previous research
- If a similar repair method is investigated for MT-UHPC, the FE modeling approach developed by the University of Connecticut could be useful





Overlay – MT-UHPC Path

- Refine the MT-UPHC-T mix design
  - Remove fly ash?
  - Optimize UW 450 admixture dosage
  - Would require many small batches with strength tests at 7 and 28 days
  - Repeat bond tests on refined mix
- Work towards full size batching for both the altered MT-UHPC and MT-UHPC-T mixes
  - Redo flexure testing
  - Potentially look into shrinkage testing (recommended by Ductal)
- Explore increasing batch size for implementation

Overlay – Proprietary Path

- Focus on **implementation** questions
- Deeper dive into literature review (specifically on Ductal)
  - Unanswered questions regarding this application
  - Structural testing needed, if so where?
- Look further into surface preparation requirements
  - Hydrodemolition or more accurate milling
- Explore MDT needs
  - Suppliers, contractor equipment (standard vs. owning/renting equipment specific to UHPC)
  - For specification – this is what machinery you need to use, these are supplier options, etc…
- Look into equipment needed for large scale batch sizing and vibratory screed
  - Currently one made by WALO being used on large scale bridge in Iowa
- Cor-Tuf?


WALO
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53570
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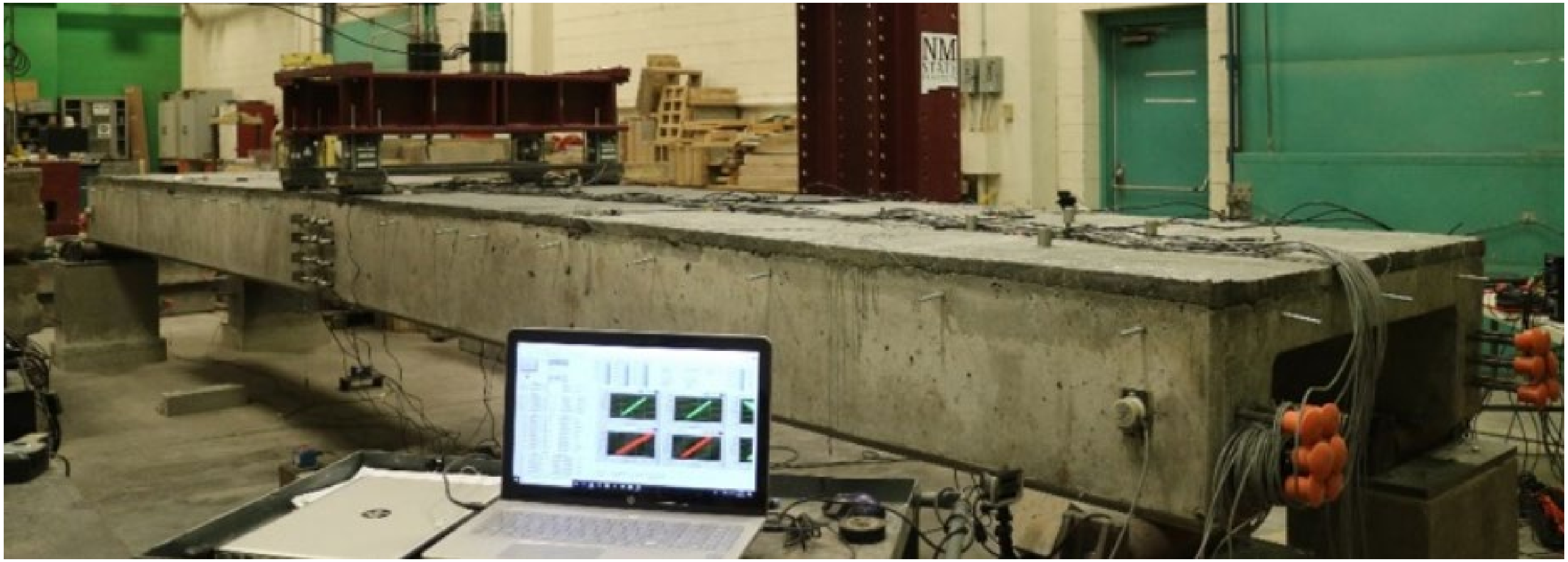
Additional Overlay Path Options

- Develop maturity curves for chosen material (thixotropic MT-UHPC or Ductal, or both?)
- Structural testing – either fill a gap(s) that MDT needs to know for implementation or confirming something before implementation
- Example unanswered question – does the overlay (in addition to making a good wearing surface and fulfilling overlay needs) increase load carrying capacity?
- Potential large-scale testing
  - Cyclic loading of beam or slab. Then apply overlay and look at strength gain.
  - Bond between slab and overlay
  - Effect of temperature gradient on bond
  - Punching shear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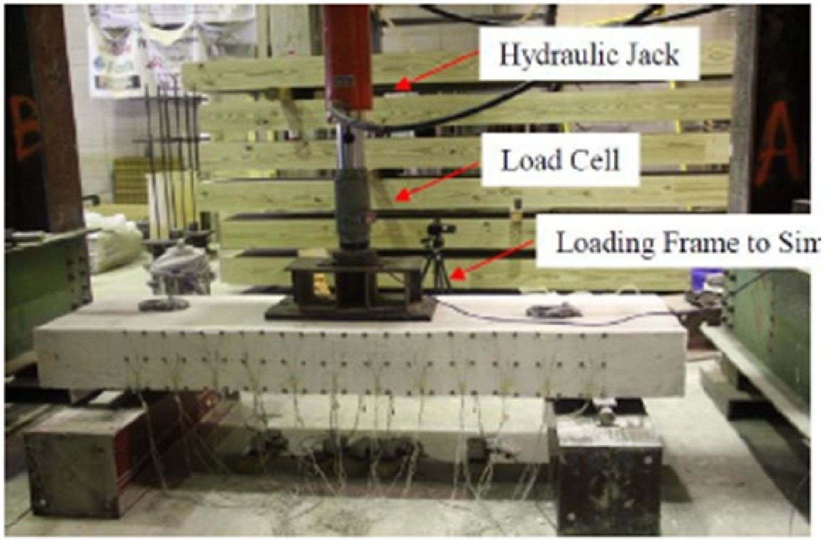
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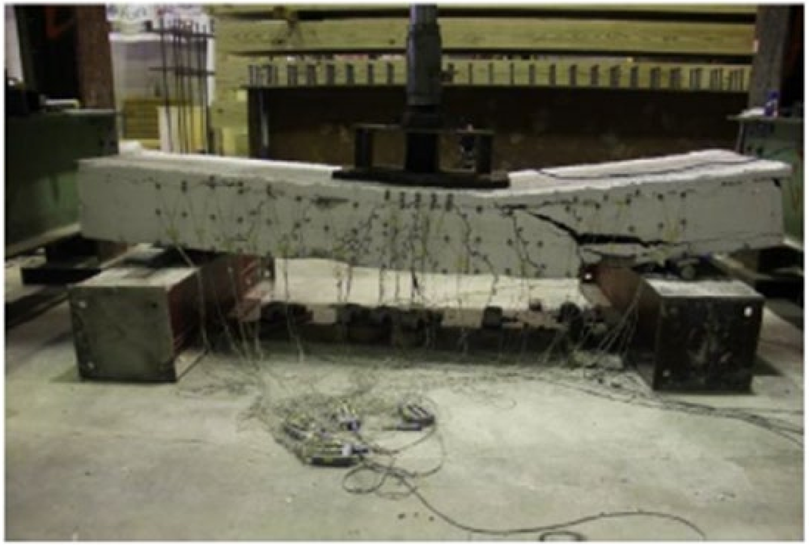

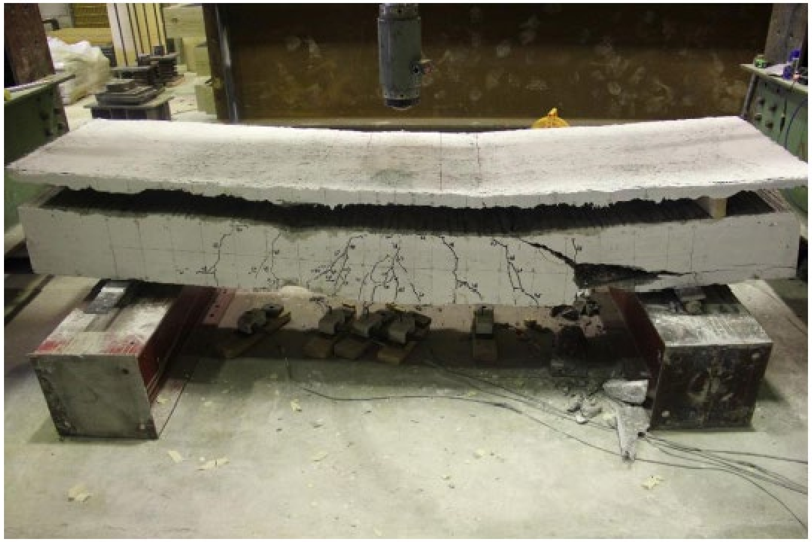

- Bridge Repair
  - Steel Girder End Repairs
    - Proprietary or MT-UHPC?
    - Small scale and then large scale
- Bridge Deck Overlay
  - MT-UHPC
    - Thixotropic mix optimization
      - Cut fly ash?
      - Admixture dosage
    - Run bond tests on optimized mix
  - Proprietary
    - Test Cor-Tuf?
    - Dive into new literature
    - Implementation Questions

Open Discussion

Thank you!